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IRRIGATION IN HUMID CLIMATES.

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IRRIGATION IN HUMID CLIMATES.

The unusually dry weather which has prevailed during the growing seasons of the past few years throughout much of the United States east of the one hundredth meridian has brought into strong relief the great importance of soil moisture in crop production. The agriculturist of the humid sections of this country is fast coming to realize, as he never has before, how essential to large crop yields is an ample supply of water at the right time.

So keenly is the need of water beginning to be felt that the practicability of irrigation east of the one hundredth meridian as well as in the arid West has come to be a serious problem in the minds of many, and already a considerable amount of capital has been invested in irrigation plants of one form or another. The question of the desirability and the practicability of irrigation in humid climates is therefore an important one, and ripe for intelligent discussion.

THE ADVANTAGES OF AN ABUNDANT SUPPLY OF SOIL MOISTURE.

It is a matter of universal experience in humid climates that on clayey soils heavy, protracted spring rains contribute more to the production of large crops of grass than all the manure which farmers can put upon their land, and that with dry springs fertilizers of whatever sort and however applied are of but little avail. So, too, four weeks of copious and timely warm rains falling upon fields of potatoes after the tubers begin to set and of corn after the tassels and silk begin to form is certain to be followed by enormous yields, even when the soil is poor, unless frost or disease intervenes. On the other hand, let the tuber and grain forming season for these crops be one of drought, and it is only those soils which are most retentive of moisture and which have been most skillfully handled that are able to mature moderate yields, even though the land be very rich.

What, then, do spring and summer rains and warm, sweet irrigation waters do in the soil which contributes so much to plant growth?

(1) They carry atmospheric oxygen into the soil, where it is indispensable in those processes by which inert nitrogenous matter is converted into the readily available nitrates so necessary for the majority of plants of the higher orders.

(2) They carry carbonic acid into the soil and absorb that which has been produced there, enabling it to attack the extremely insoluble

phosphates and silicates of the soil, setting free the phosphoric acid, potash, lime, and magnesia compounds without which no plant is able to mature its fruit.

(3) They carry atmospheric nitrogen into the soil, and thus help replace the nitrogen which is constantly running to waste in the drainage waters or escaping back into the air.

(4) Coming from the warm air and soaking through the hot surface, they carry deeper into the soil the warmth which makes the root action of plants more powerful, cause the phosphates and potash to be dissolved more readily, and greatly stimulate the production of available nitrogen compounds by the microscopic organisms which abound in the soil.

(5) Then, again, rains, as already explained, carry small amounts of nitrogen compounds with them to the soil, and most natural irrigation waters, in addition, contain some potash, phosphoric acid, and considerable quantities of lime, magnesia, and sulphuric acid.

It is not strange, therefore, that an abundance of warm, sweet water applied to fields at opportune times and retained there by judicious and thorough tillage enables even poor soils to bring forth large yields.

It is the possibility of supplying an abundance of water to the soil at the right time which makes irrigation farming so much more certain and the average yields so much larger than obtain under the ordinary conditions and methods of humid climates.

The plant feeding and growing in the soil is like the animal coming to maturity and fattening in the stable—it can not at any stage receive a serious check to its growth and come out at the end of the season with that vigor and total product which result where no hindrance intervenes.

Just as soon as the amount of soil moisture in the surface foot of a crop-bearing field falls below a certain percentage, the soil's ability to supply food is decreased and the growing crop soon reaches a point where it is not furnished with plant food as fast as it demands it, the inevitable result being a diminished rate of growth and ultimate starvation.

THE RAINFALL OF THE GROWING SEASON IN THE UNITED STATES IS INSUFFICIENT FOR MAXIMUM YIELDS.

Those seasons are very rare indeed in most parts of the United States which bring to the soil a supply of rain adequate to permit the maximum amount of plant food to be elaborated in it or to be removed from it by growing crops.

It is almost invariably true that as a crop advances toward maturity its spread of leaf surface becomes so great that the loss of water from the surface soil through the plant is much more rapid than the rise of water from below and the fall of rains from above are able to supply, the result being a reduction of the rate of plant growth.

The writer has succeeded in growing, under field conditions, on one eighteenth of an acre, more than 14.5 tons of water-free substance in flint corn and 83.5 bushels of kiln-dried shelled corn per acre by supplying all the water which the plants could use and at the right time. Under similar conditions common red clover yielded over 4 tons of hay in the first crop. The second crop on the same land exceeded 2 tons per acre, while the third growth was heavy and 6 to 8 inches high. It should be said, too, that these results were obtained without the aid of manure or fertilizers of any sort, that the water used was pumped from an ordinary lake, and that the land was a clay soil in only fair condition.

Potatoes have been grown in pots holding 500 to 600 pounds of soil, so arranged that they could be weighed at any time and an exact knowledge of the amount of soil moisture present ascertained; and yields as high as 695 bushels of tubers to the acre have been secured, using 24 inches of water, which is more than falls during the growing season of this crop in Wisconsin. Flint corn under similar conditions was made to produce at the rate of 17⅓ tons of water-free substance per acre; but to do this it required 34¼ inches of water, an amount which more than equals the mean rainfall for the whole year; and it is certain that had a less quantity of water been used the crop would have been smaller.

WATER ONLY ONE OF THE NECESSARY PLANT FOODS.

It is not at all strange that the ancient Egyptian and Grecian philosophers, with their lack of exact knowledge and under their arid climatic conditions, should have come to believe that water is the sole food of plants; nor that this opinion should have been held until nearly the beginning of the eighteenth century. As a matter of fact, water does contribute more than half of the material which makes up the dry matter of plants, and as water it constitutes from three-fourths to more than nine-tenths of their green weight.

But while these are the facts, and while it is true that abundant and timely rains do make comparatively poor soils produce large yields, it must not be inferred that with ample and timely supplies of water applied to the soil, all else may be neglected and the hope entertained that any agricultural soil will thus be held up to a high state of productiveness for an indefinite term of years.

It is a matter of universal experience that sewage waters, not contaminated with poisonous compounds and not too concentrated, cause land to give much larger returns than river, lake, or well water. The writer learned, while visiting the celebrated Craigentinny meadows near Edinburgh, that the purchasers of the grass from those lands are very particular to specify, as a condition of their purchase, that their grass shall be watered with the day sewage, which contains a higher percentage of soluble and suspended organic matter than that of the night; and they are also particular to stipulate that they shall have the first rather

than the second or third use of the water, knowing that water which has passed over a cultivated field or meadow has lost something of its fertilizing value.

It is claimed also by the owners and renters of water meadows in the south of England, where the irrigation is directly from the streams, that that land which received the water first was most benefited by it. It is true that there are those who claim that on their lands the second and third waters are as good as the first, but this is probably due to the presence in those particular soils of an abundance of the substances carried by the waters.

It is impossible to overestimate the importance of water as a plant food. It is indispensable, and is used more than any other substance. It must be borne in mind, however, that water is not usually a complete plant food.

ADVANTAGES AND DISADVANTAGES OF IRRIGATION IN HUMID CLIMATES.

Where irrigation waters can be economically applied to lands it has some important advantages in crop production over the natural rainfall, even where that is large. In the first place, irrigation waters can be applied at such times and in such quantities as they are needed, and this gives a certainty to results which is impossible where the outcome must depend upon the chances of adequate or inadequate, timely or untimely, rainfall.

Where the natural rainfall must be depended upon it is imperative that only so many plants be allowed to occupy the soil as are likely not to increase the loss of soil moisture beyond what the rains and tillage will make good, whereas by irrigation methods the closeness of stand upon the ground is limited only by the demands for root room, air, and sunshine. Since many more plants can be grown upon an acre by irrigation than otherwise, the yield will be much larger; because, no matter how much we may crowd a plant by feeding, there are inherited limits of stature beyond which we may not hope to pass, and a few plants, even if of abnormal proportions, can never equal in aggregate yield a large number of individuals of normal stature.

Then, too, waters used for irrigation contain almost without exception much larger percentages of both the organic and the ash ingredients of plant food than rain waters do, and, as this is largely in the soluble form, it becomes at once available, and thus stimulates vigorous growth.

Setting matters of expense aside in this consideration, there are disadvantages and dangers attending irrigation in humid climates which should not be lost sight of by those who are thinking of adopting this practice.

It not infrequently happens in arid countries that inexperienced men apply so much water that the soil is water-logged and the crops injured

or destroyed. In humid climates there is the additional danger of heavy or protracted rains following immediately upon the thorough irrigation of a field. From this it follows that all lands in humid climates intended for irrigation must be thoroughly drained, either naturally or by artificial methods.

It may be said, however, that the danger of water-logging soils by irrigation is not as much greater in humid than in arid regions as many appear to think. On account of the tendency of all heavy soils to puddle and bake after they have been thoroughly saturated with water, and because the surface soils are inevitably brought into this condition on considerable portions of the field—if not over its whole area—where irrigation is practiced, while this only rarely occurs after natural rainfalls, it follows that in this respect irrigation waters are not as good as the natural rains. Where the soils are sandy and light, however, the danger in this direction is greatly reduced or entirely disappears.

While the amount of water available for purposes of irrigation in humid climates is much larger than it is in arid regions, there is, nevertheless, not enough to irrigate all farming lands were that desirable, and while it is true that thorough and careful irrigation in most parts of the United States east of the one hundredth meridian would more than double the average yield per acre of almost all crops now raised, it can not be said that the time has yet come when it is desirable to use all available water for purposes of irrigation.

We are yet a long way from having exhausted our resources in the direction of improved methods of tillage which shall conserve and turn to better account the waters which fall as rain. Moreover, the density of population is not yet great enough to consume the increased product which would result from thorough irrigation to the extent which the available water would permit.

But while the time is not ripe for the Middle, Eastern, and Southern States to apply methods of irrigation in any general way or on an extensive scale, we have, nevertheless, reached a point where a very large number of people who are favorably situated with reference to water, soil, and market can well afford to think about developing irrigation plants upon their lands, and this is especially true if the farm is not large enough to fully occupy the available time and energies of its owners by the ordinary methods.

EXTENT OF IRRIGATION IN THE HUMID PARTS OF EUROPE.

The writer had an opportunity in the summer of 1895 to visit and study irrigation districts in various parts of Scotland, England, France, Italy, Switzerland, Germany, Holland, and Belgium. While it can not be said that the art of irrigation is practiced generally in any sections of Europe except near the borders of the Mediterranean Sea, yet the total acreage is large. Wilson,[1] in speaking of the extent of irrigation,

[1] Manual of Irrigation, p. 1.

places the acreage of Italy at 3,700,000, which is approximately 1 acre in every 16 of the total area. In Spain 500,000 acres are said to be irrigated, and in France 400,000 acres, which, in round numbers, is 1 acre to every 245 in Spain and 1 in every 321 in France. The writer has not access to the literature which would enable him to verify these statements, and, judging from impressions gained while traveling, they seem too high; but, however this may be, there is without doubt a very large acreage of irrigated lands in these countries.

THE RAINFALL OF EUROPE AND THE EASTERN UNITED STATES COMPARED.

If we compare the rainfall of Europe, exclusive of Russia, with that of the United States east of and including Minnesota, Iowa, Missouri, and Arkansas, we shall find that Europe has a mean precipitation ranging from 24 to 40 inches, and that the portion of the United States in question has a rainfall ranging from 26 to 55 inches. Eastward from and including Michigan and Indiana the precipitation for the year amounts to from nearly 36 to 50 inches, while south of Tennessee and North Carolina it ranges from 43 to 67 inches. It is true that in the Pyrenees and in the Alps and on the coast of Norway the yearly precipitation is greater than that stated above, but with these exceptions the total rainfall of western and southern Europe is very materially less than that of the eastern United States, the difference ranging from 2 inches to more than 16 inches per annum.

It should be stated, too, in connection with this larger rainfall in the United States as compared with that of Europe, that the seasonal distribution with us is unusually favorable to crop production, for we get the least in the three winter months and the most in the three summer months, when there is greatest need for it.

The seasonal precipitation in the humid portion of the United States is approximately as follows: For the three winter months it ranges from 3.5 inches in the West to 18 inches in the East or South; in the spring the range is from 8.5 inches to 22 inches; in summer from 11 inches to 24 inches, and in autumn the range is from 6 inches in the West to 20 inches in the South and East.

It would appear from what has been said regarding the differences between the rainfall in the United States and that in Europe that there will be less occasion to irrigate here than there, and this, in a considerable measure, is true, especially when reference is had to the Atlantic and Gulf States.

It must be borne in mind, however, that while our total rainfall is larger than that of Europe our mean summer temperature and total amount of sunshine are both higher, and the air, as a rule, is also less moist, and that under these conditions the water is lost more rapidly by evaporation than under the conditions which prevail in the greater part of Europe.

In Italy, where irrigation is most generally and systematically practiced, the mean annual rainfall is about 37 inches, and of this amount 28 inches fall during the seven months which are suited to irrigation.

THE CHARACTER AND ANTIQUITY OF EUROPEAN IRRIGATION.

If we leave out of view sewage irrigation as practiced in the vicinity of large cities, it must be said that north of Italy and southern France nearly the whole of irrigation effort is devoted to raising hay and grass for soiling and pasture. This is particularly true of England, Holland, and portions of Germany and of the mountainous parts of France and Switzerland. It should also be noted here that in those Alpine districts where the rainfall is largest irrigation is most general, not because it is most needed there, but because it is more readily and cheaply secured than elsewhere, and because it pays.

In the south of France irrigation is extensively applied to olive and almond orchards, and the same is true of parts of Italy. In the Po Valley, naturally fertile but made more so by thorough and very systematic irrigation, water is artificially applied to almost all crops. Corn is here very extensively raised by irrigation. To convey some idea of the extent of this work, it may be stated that on August 7, 1895, while riding from Turin to Milan, the writer noted between Chivasso and Santhia, a distance of 18.5 miles, the irrigation of 100 fields of maize, ranging in size all the way from 4 to 20 acres. Wheat, barley, rice, and hemp, as well as rye grass and clover, are among the ordinary field crops which are extensively irrigated in the Po Valley. So, too, very extensive mulberry orchards are grown, the trees usually being set along the main and distributing canals, while the space between them is occupied by various kinds of farm crops.

The art of irrigation as practiced in European countries is not new. Two large canals in Lombardy which irrigate 250,000 acres were dug as long ago, Marsh tells us, as the twelfth century, while earlier still, at the time of the invasion of the Moors, very extensive systems of irrigation were introduced into Spain and southern France.

In England, too, the water meadows are so old that no one appears to know by what people they were introduced. Indeed, the present occupants of these lands speak of them as having always been irrigated in this manner.

It will be evident, therefore, from these facts, that irrigation under the climatic conditions of Europe must possess some substantial merits or it would not have persisted through all these years; and since it has been so extensively developed under the humid conditions of Europe, there seems little reason to doubt that irrigation may be found remunerative within suitable limitations in that part of this country lying east of the one hundredth meridian.

FERTILIZING VALUE OF IRRIGATION WATERS.

In traveling from place to place in Europe it was a continual surprise to the writer to learn from those who were practicing irrigation that the fertility which the river waters added to the soil was regarded as the chief advantage derived from them; and so thoroughly grounded is this idea in many places that large volumes of water are run over the land during the winter season or whenever it is not occupied by a crop. Indeed, on the water meadows of England it is the practice to have the water running over them just as much as possible, and it is claimed that the longer it can be kept running during the winter, when the weather is not too frosty, the larger will be the crop of grass the following season.

As an example of the amounts and kinds of material which would be added to an acre of land where exceptionally pure river water is used to a depth of 24 inches, we have calculated from a chemical analysis of the water of the Delaware River[1] as follows:

Materials in 24 acre-inches of Delaware River water.

	Pounds.
Calcium carbonate	242.60
Magnesium carbonate	166.16
Potassium carbonate	31.74
Sodium chlorid	20.54
Potassium chlorid	1.86
Lime sulphate	35.48
Lime phosphate	26.14
Silica	93.34
Ferric oxid	5.60
Organic matter containing ammonia	117.62
Total	741.08

The average amounts of nitrogen compounds, as computed from the chemical analyses of the waters of twelve streams in New Jersey, are as follows:

Nitrogen compounds in 24 acre-inches of water from New Jersey rivers.

	Pounds.
Free ammonia	15.63
Albuminoid ammonia	81.12
Nitrates	772.67
Nitrites	0.86
Total	870.28

When it is observed that these analyses were all made from streams where the water is regarded as pure, it is plain that there is a considerable foundation for the opinion held in European countries regarding the fertilizing of lands by irrigation.

In further illustration of the fertilizing value of the water of rivers in humid climates, it may be said that the amount of materials held in solution in the waters of the Mississippi and St. Lawrence rivers, in

[1] Rpt. New Jersey Geol. Survey, 1868, p. 102.

North America, and the Amazon and La Plata, in South America, is such that the average of the four would yield 655.6 pounds of solid matter for every 24 acre-inches.

Goss and Hare[1] found from analyses of the water of the Rio Grande at different periods from June 1 to October 31 that 24 acre-inches of the water added to the soil (in sediment and water) about 1,075 pounds of potash, 116 pounds of phosphoric acid, and 107 pounds of nitrogen. The water of this river is unusually rich in sediment, 2 acre-feet furnishing 81,309 pounds.

Where lake waters are used for irrigation larger amounts of fertilizing materials will usually be applied to the land than in the case of river waters, because in the lakes the salts are concentrated by evaporation.

Where there are such considerable quantities of plant food dissolved in river waters as the figures cited show, it must be evident that the fertilizing value of such waters is not inconsiderable. It is more valuable, too, pound for pound, than solid commercial fertilizers which we buy, because it is already in solution and ready to be taken up immediately and by all rather than a few roots of a crop to which the water is applied.

The water meadows of England have been in constant service as such, without rotation, and without the application of barnyard manure or commercial fertilizers of any kind, from time out of mind, perhaps during 150 or possibly 300 or 500 years, and yet they are said to be as productive to-day as they ever were. Sometimes the meadows are pastured by sheep being hurdled upon them very early in the spring before there is danger of fluke rot, and by cattle late in the fall, but except this the products of the land are yearly taken from them and never returned in the form of manure.

As a matter of fact, these water meadows are made to catch and fix again, and at once, the nitrates, potash, and phosphoric acid which are carried by the drainage waters from the higher lands, converting them into rich grass, which is fed to sheep and cattle, producing flesh and milk for the market or manure which is spread upon the higher lands.

It should be kept in mind, however, that the amount of water applied to these meadows is very large, probably each season many times the 24 acre-inches which we have used in the above estimate of the amounts of plant food which irrigation waters carry, and it is in this way that their high state of productiveness is maintained.

All farmers who own these lands esteem them very highly because (1) they are able to water them far more cheaply than they can haul manure upon them, even if it cost them nothing more than the hauling; (2) they are absolutely certain of a known amount of feed, and (3) with 20 or 40 acres of such land they are able to maintain a high state of productiveness on their unirrigated lands through the use of the manure made from the product of the meadows.

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[1] New Mexico Sta. Bul. 12.

LINES ALONG WHICH IRRIGATION SHOULD FIRST DEVELOP.

It has been pointed out that the time has not yet arrived for a full utilization of the water resources of the eastern United States for purposes of irrigation. There are certain lines, however, along which labor and capital may be profitably invested, and some of these may now be mentioned:

(1) *The kitchen garden.*—There is no more important adjunct of the country home than the kitchen garden, nor can there be any question about the desirability of managing it in such a way that a high degree of productiveness shall be insured whether the season be wet or dry. The health of the family demands this, and the housewife who must plan for and secure the needed variety in three times 365 meals in the year should be expected to accept nothing less.

The only way to make these gardens a certainty in a very large part of even the humid portion of the United States is to apply irrigation to them. As these gardens should range from one-fourth of an acre to an acre and a half in area, the aggregate amount of land thus treated would be very large.

(2) *Market gardening.*—This is an industry in which a large income is expected from a small area, and because of this it is one upon which larger expenditures per acre are permissible, and in which curtailment of yield or injury to quality through drought is most disastrous. It is therefore a type of plant husbandry eminently suited to irrigation in humid climates.

(3) *Small-fruit culture.*—Strawberries, raspberries, and blackberries are all extremely sensitive to drought and much reduced in yield by a shortage in soil moisture, while the value of the crop per acre is so large that irrigation may be practiced with advantage where the rainfall of early summer or the capacity of soil to hold water is small.

(4) *Cranberry culture.*—There is perhaps no crop raised in humid climates where the water conditions need to be under such complete control as for cranberries. Where the winters are severe the vines need to be largely submerged in water and so held until the killing frosts of spring are passed. Then it not infrequently happens that the vines must be flooded to avert the ravages of insects, or as a protection against frosts at or just before the time of harvest. It may therefore be said that thoroughly successful cranberry culture is impossible where an abundance of water is not at command.

(5) *Dairy husbandry.*—Where the price of both lands and milk is high and where an abundance of water can be had at a low cost, capital may find remunerative investment in the development of water meadows and in the production of corn for the silo and for soiling; for under a thorough and judiciously applied system of irrigation the amount of coarse feed may be so much increased that the number of cows carried upon the land may be doubled.

LANDS BEST SUITED TO IRRIGATION IN HUMID CLIMATES.

The lands best suited to irrigation are those to which the water may be carried in large quantities by gravity and over relatively short distances, because these conditions will usually reduce the cost of water to the minimum. Moreover, the lands must not be so flat that there is difficulty in leading the water over the surface, nor so steep that it is difficult to prevent washing. It is possible to lead water over steep slopes, particularly if the lands are in grass, if proper care is exercised.

The lighter types of soil as a rule will be most benefited by irrigation in humid climates, not only because of the naturally small water capacity and consequent deficiency of water supply for large yields, but because such soils are less liable to be seriously injured in tilth by injudicious applications of water, and because they are generally unable, owing to their coarser grained structure, to yield as large amounts of plant food with the natural rainfall as the finer types of soil are capable of giving. It should be understood, however, that the heavier types of soil may be irrigated with profit where water is easily accessible and where thorough drainage is readily secured, although in these cases, except when the lands are in grass, great care must be exercised not to puddle the soil and not to allow it to dry and become cloddy.

WATERS BEST SUITED TO IRRIGATION.

It may be said, as a general rule, that the best waters for irrigation are those having the highest temperature and containing the largest amounts of suspended and dissolved mineral matter, provided the materials carried by the water are not injurious to plant life.

Without question the water of highest value for irrigation is the sewage of cities when it is adequately diluted and when it does not contain poisonous chemicals from the waste of factories. Sewage which is so turbid as to leave a coating of sediment upon the land is liable to work injury by clogging the pores in the surface soil and thus interfering with its proper aeration; but sewage of this character is the exception rather than the rule.

The amount of sewage discharged into streams and lakes is extremely large, and if irrigation in the humid sections of the United States is to be entered upon, it is important that attention should be directed to the fact that the utilization of sewage for crop production need not be limited to sewage farms, for a very large amount of sewage now is and will continue to be for a long time discharged into streams and lakes to run to waste. It will very often happen, particularly in the case of sewage-bearing streams, that irrigation plants may be so placed as to utilize these impure waters and, other conditions being equal, those lands which can be irrigated with this class of waters will pay the largest interest on the money invested. In arranging, therefore, to take the water out of such streams care should be taken to so place the intake

below the city or town that it may draw upon the most impure water which passes. It will even be practicable in some cases to divert the sewage-bearing portion of the stream to one side and thus prevent it from becoming unnecessarily diluted before reaching the point where it is to be used.

Next in value to warm sewage waters stand those which are muddy or which carry in suspension a large amount of sediment, and there are no soils upon which such waters will be more helpful than upon those which are coarse and sandy, for in these cases the fine silt will help to improve the texture and greatly increase the water-holding power. Aside from this effect of silt upon sandy lands, the amount of fertilizing ingredients which it contains is very large, and hence such water is valuable upon any land suitable for irrigation. This being true, it will often be found desirable to irrigate certain lands in the winter, and particularly early in the spring, when the river water is turbid, even though the land may already be saturated with water.

There are very many sections of country where the topography is abrupt and hilly, and particularly when ravines lead through fields, where it would be possible, by a system of broad, wattle-like ridges not high enough nor abrupt enough to seriously interfere with tillage, to so check the surface washing of fields as not only to prevent gullying, but at the same time to retain the water and the fertility which would otherwise pass from the fields into the streams.

While, therefore, the most impure waters are likely to prove best for irrigation it is nevertheless true that the purest and softest of waters will be found very helpful when used under favorable conditions. There are occasionally some natural waters which are positively injurious when applied to the land. These usually issue from peaty or boggy swamps. The injurious properties of these waters are due to the sulphate of iron which they contain.

AMOUNT OF WATER NEEDED FOR IRRIGATION.

The amount of water needed for irrigation varies within wide limits, being affected by the climate, weather, kind of soil, variety of crop, manner of application of the water, and by the character of cultivation which the field receives subsequent to irrigation.

Let us first consider the amount needed for a single watering. This must be determined by the amount of water the soil contains at the time it is to be irrigated and by the amount it should contain in order that plants may do their work to the best advantage.

The maximum capacity of upland field soils for water ranges from about 18 per cent of their dry weight for the light sandy types to about 30 per cent for the heavy clayey varieties, while the amounts of water these soils should contain in order that plants may thrive in them best is from 12 to 14 per cent for the former and from 18 to 20 per cent for the latter. The growth of plants will be seriously checked in sandy

soils when the water content falls below 8 per cent, and in heavy, clayey types when it falls below 14 per cent of the dry weight of the soil.

The dry weight of a light sandy soil and subsoil will average about 105 pounds per cubic foot, and the heavy, clayey type about 80 pounds per cubic foot. Hence the maximum amount of water per cubic foot of soil would be about 24 pounds for the clay and 18.9 pounds for the sand. This being true, 4.6 inches of water on the level would completely saturate the surface foot of heavy clay soil, were it entirely dry to begin with, while 3.6 inches would place the sandy soil in a similar condition.

But since water should be applied as soon as the water content of the sandy soil falls to 8 per cent and that of the clayey soil to 14 per cent, it follows that under these conditions 10.5 pounds of water, or 2 inches, is the maximum amount which would be needed to fill the surface foot of sandy soil and 12.8 pounds, or 2.46 inches, is enough to fill the surface foot of clay soil.

If we consider the second foot of soil to have been dried out to a corresponding extent, and that it is desirable to saturate this with water also, then the amounts just stated would need to be doubled, 4 inches being demanded for the sandy soil and 4.92 inches for the clayey soil. It is quite certain, however, that such an application of water to a field at one time would result in the percolation of a considerable amount of this water below the depth of root action, and hence in a considerable loss of it unless a large crop were growing upon the land at the time. It appears, therefore, that the amounts of water which may be applied to a field at one time will lie between 2 and 5 inches in depth over its whole surface.

How often this watering may need to be repeated it is not possible to state in anything like definite terms, but practical experience shows that as a rough average the intervals between watering where maximum yields are sought can not much exceed 7 to 14 days, the time being shortest when the crop is making its most vigorous growth.

In experiments at the Wisconsin Station during 1895 corn was irrigated once about every 7 to 9 days, applying at each time 4.43 inches of water. The corn, however, was planted very thickly upon the ground, the rows being only 30 inches apart and the hills 15 inches apart in the row, with from 2 to 5 stalks in each hill. The first irrigation was given June 26 and the last August 15, the total amount of water applied being 26.6 inches. The yield produced was 11,125 pounds of water-free substance per acre.

In the case of the water meadows of Europe very little attention is paid to the natural rainfall, the irrigation waters being applied whenever it is possible to do so, and whatever rains fall are counted as so much additional gain. It is true, however, that on most lands with crops other than grass attention would have to be given to the natural rainfall in the application of water by irrigation lest oversaturation of the soil and a positive waste of water should occur.

If it is regarded that ample irrigation has been provided when 2 inches of water is supplied every 10 days as a minimum and 4 inches as a maximum, then to meet this demand there would be required for 1 acre a continuous flow of water at the rate of 0.5042 cubic foot, or 3.77 gallons, per minute for 2 inches and 1.008 cubic feet, or 7.54 gallons, per minute for 4 inches. An area of 10 acres would require a rate of flow 10 times as rapid, or 5.04 cubic feet per minute for the minimum and 10.08 for the maximum.

These amounts of water expressed in cubic feet and in gallons are as follows:

	Cubic feet.		Gallons.
For 1 acre 2 inches deep,	7,260	=	54,310
For 1 acre 4 inches deep,	14,520	=	108,620
For 10 acres 2 inches deep,	72,600	=	543,100
For 10 acres 4 inches deep,	145,200	=	1,086,200

If these amounts of water are stored in circular reservoirs with vertical sides and 3 feet deep their diameters will be, respectively, 55.5 feet, 78.6 feet, 175.5 feet, and 248.5 feet.

METHODS OF OBTAINING WATER FOR IRRIGATION.

LEADING OUT WATER FROM STREAMS.

The simplest and most usual method of obtaining water for purposes of irrigation is to lead it out from streams. This is done by cutting a ditch or canal along the highest portion of the river valley over which the water can be led in the direction of the general fall or slope of the country, and in valleys where the fall is large it is possible to lead the water off to such distances that extensive areas may be thus supplied with water.

HOLDING AND DIRECTING STORM WATERS.

In other cases the storm waters are utilized before they have had time to reach the main water ways. This is done by constructing dams and reservoirs at points where several ravines or draws join, thus holding the water back, either to be used later in the season as desired or led out at once upon meadow lands, obliging it to drain through or flow so slowly over them that most of the fertility, whether suspended or dissolved, is deposited upon or in them. Extensive areas are thus irrigated in the southwest of England and in the hilly and mountainous parts of France, Switzerland, Italy, and Spain.

LEADING OUT THE UNDERFLOW FROM HIGHER LANDS.

There are many localities, especially in hilly countries, and oftentimes along the side of a river valley, where a terrace rises to a considerable height above the flood plane from which water is continuously but slowly oozing from the ground, and to such an extent as to keep it swampy and unfit for agricultural purposes. In many such cases the water can be led out by underdraining upon lower lands and stored in reservoirs to become warm, and then applied to the surface for irrigation, at the same time rendering the land from which the water has been withdrawn fit for cultivation.

Besides the deeper artesian waters which are available in many localities for irrigation purposes, there are a larger number of localities where "flowing wells" of the artesian type may be had and their waters used for the irrigation of small areas. In these cases the water may often be raised to a height of several feet above the ground and thence led away to where it would be valuable for irrigation in either a kitchen or market garden. Often such wells will supply the equivalent of a 1-inch stream flowing 4 miles per hour, which is water enough to irrigate to a depth of 4 inches every 10 days 2.42 acres of land, or about 5 times the area a 3-inch piston with a 12-inch stroke will control when working 8 hours a day and making 30 strokes a minute.

LIFTING WATER BY ITS OWN POWER.

Where the beds of streams lie below the level of the area which it is desired to irrigate it becomes necessary to employ lifting devices of one

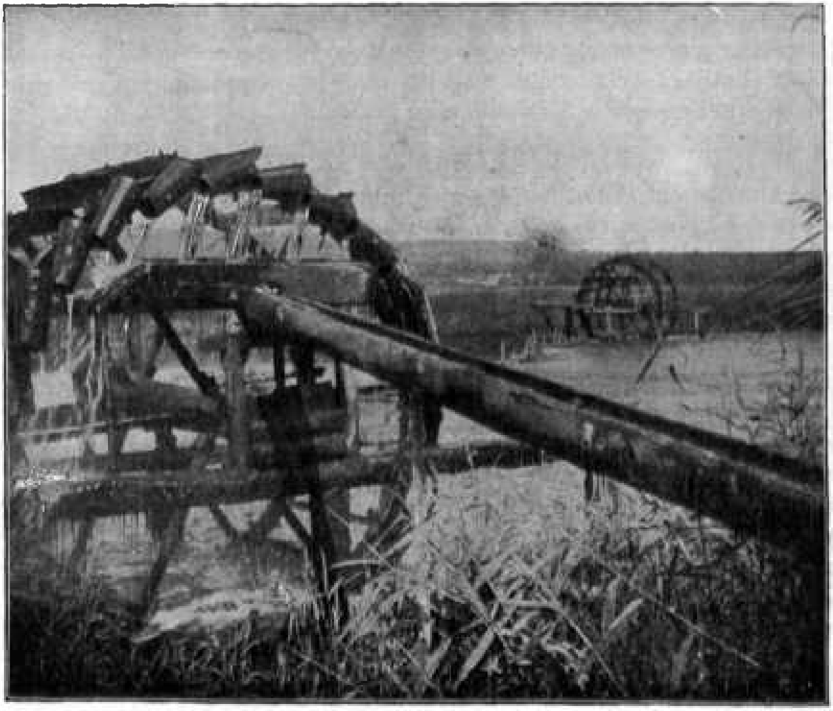

FIG. 1.—Water wheel at Baiersdorf, Bavaria.

form or another in order to bring the water to a level at which it can be led over the land, and there have been invented various devices by which a portion of the energy of a stream is turned to use in lifting another portion of the stream to a height at which it may be utilized for irrigation.

Where the stream is large in proportion to the water which it is desired to lift, and where the height to which the water must be raised

is not great, a very old device is the undershot water wheel provided with buckets near the circumference. Fig. 1 represents a wheel of this kind much used in Bavaria on the river Regnitz, a branch of the Main, where the writer counted no less than 20 in a distance of $1\frac{1}{4}$ to $1\frac{1}{2}$ miles.

These wheels have a diameter of 16 feet and carry upon one or both sides a row of 24 churn-like buckets each lifting out of the stream, and to a height of 12 feet, not less than 3 gallons of water, emptying it into the side trough shown in the figure, from which it is conveyed to the bank through a conduit hewn from a log. The wheel under consideration was making at the time of the writer's visit 4 revolutions each minute, so that the water lifted was not less than 288 gallons per minute, and probably exceeded 300 gallons. Another wheel with a row of buckets on each side was making 3 revolutions and discharging not less than 450 gallons per minute. The first of these wheels was pumping water at a rate sufficient to irrigate, to a depth of 4 inches every 10 days, 38 acres and the second wheel 60 acres.

In other places where the water must be lifted to a greater height one or another form of water wheel is made to operate a pump, or again in still other cases the hydraulic ram is used.

LIFTING WATER BY WIND POWER.

At the present time there is much talk about the utilization of wind power for irrigation purposes, and where the areas to be irrigated are small, and particularly where the lift is very low, the windmill makes a cheap and effective motor for lifting water, but a single mill never can be depended upon to do work on a large scale.

As the windmill is at present used upon a piston pump, it will be helpful to consider what work can be done by piston pumps under different conditions, and in the table below is given the number of days required to pump the amount of water needed to irrigate 1 acre to the extent of 2 inches and 4 inches, respectively, with a single-acting piston pump working 8 hours per day and making 30 strokes per minute:

Number of days required to pump 2 and 4 acre-inches of water with a single-acting piston pump working 8 hours per day and making 30 strokes per minute.

Diameter of piston.	Time required to pump 2 acre-inches with—		Time required to pump 4 acre-inches with—	
	6-inch stroke.	12-inch stroke.	6-inch stroke.	12-inch stroke.
Inches.	*Days.*	*Days.*	*Days.*	*Days.*
3	20.5	10.3	41.1	20.5
4	11.6	5.8	23.1	11.6
5	7.4	3.7	14.8	7.4
6	5.1	2.6	10.3	5.1
7	3.8	1.9	7.5	3.8
8	2.9	1.4	5.8	2.9
9	2.3	1.1	4.6	2.3
10	1.8	0.9	3.7	1.9
11	1.5	0.8	3.1	1.5
12	1.3	0.6	2.6	1.3

It is claimed by Wolff that the average length of a day's work for windmills in the United States is 8 hours, and they are not likely to average more than 30 strokes per minute where single-acting pumps are used; and this being true, the table above shows what the range of work done by the windmill may be when used for irrigation if worked upon pumps such as are indicated in the table.

It is generally conceded by the best authorities on the subject that existing data bearing upon the actual work which windmills are able to do when used for irrigation are not sufficient to enable tables to be constructed which will show what wheels of different pattern and sizes may be expected to do when set up in different sections of the United States. But if windmills can be set up which will work single-acting pumps at the rate and under the conditions indicated in the table above, then the areas to which 2 acre-inches and 4 acre-inches of water may be applied every 10 days would be as follows:

Areas irrigated by windmills working single-acting pistons 8 hours per day at the rate of 30 strokes per minute.

Diameter of piston.	2 inches every 16 days.		4 inches every 19 days.	
	6-inch. stroke.	12-inch stroke.	6-inch stroke.	12-inch stroke.
Inches.	*Acres.*	*Acres.*	*Acres.*	*Acres.*
3	0.49	6.97	9.24	0.49
4	6.87	1.73	6.43	6.87
5	1.35	2 76	6.98	1.35
6	1.95	3.89	6.97	1.95
7	2.05	5.36	1.33	2.65
8	3.46	6 92	1.73	3.46
9	4.38	8.79	2.16	4.38
16	5.41	19.82	2.70	5.41
11	6.55	13.69	3.27	6 55
12	7.79	15 58	3.89	7 79

From this table it appears that if windmills can be constructed which will work pumps at the rates here assumed, areas varying from 0.24 acre to 15.58 acres may be irrigated at rates of 2 to 4 inches every 10 days.

Wolff[1] gives a table showing the capacity of first-class windmills for work in irrigation, which is based upon results actually attained in practice, and from this the following table is computed:

Number of acres a first-class windmill will irrigate 2 and 4 inches deep every 10 days when working 8 hours per day and lifting the water 10, 15, and 25 feet, respectively.

Diameter of windmill wheel.	Lift of 19 feet.		Lift of 15 feet.		Lift of 25 feet.	
	2 inches.	4 inches.	2 inches.	4 inches.	2 inches.	4 inches.
Feet.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
8.5	1.35	9.67	0.9	9.45	9.55	9.27
10	4.27	2.13	2.85	1.42	1.70	0.85
12	7.66	3.83	5.11	2.55	3.60	1.50
14	9.87	4.93	6.58	3.26	3.99	1.66
16	13.79	6.89	9.19	4.59	5.71	2.85
18	22.66	11.94	14.14	7.07	8.64	4.32
26	27.36	13.98	18.25	9.12	11.94	5.52
25	47.06	23.53	81.38	15.99	18.77	9.38
36	95.46	47.73	64.42	32.21	38.68	19.64

[1] The Windmill as a Prime Mover.

It will be seen that according to this table the largest area which can be irrigated to a depth of 4 inches in every 10 days by a 12-foot wheel, lifting the water 25 feet, is 1.5 acres. It should be said in connection with this table, however, that with the improvements which are being made both in the construction of windmills and of pumps adapted to them it is quite probable that considerably higher efficiency will be attained.

LIFTING WATER WITH ENGINES.

When it comes to lifting water with engines for purposes of irrigation the amounts so raised to considerable heights at a comparatively small cost for fuel become very great.

It is claimed that at the present price of gasoline the gasoline engines now made will produce 1 applied horsepower at a cost of 1 to 1.5 cents per hour for fuel. At the higher figure the water necessary to irrigate 1 acre to a depth of 4 inches could be lifted 20 feet high at a fuel cost of 14 cents, and if the irrigation were repeated six times the total cost per acre for fuel alone would be only 84 cents.

At the Wisconsin Station, with a rated 8-horsepower farm engine, water has been drawn from a lake through 110 feet of 6-inch suction pipe to a height of 26 feet at the rate of 22⅛ acre-inches per day, with 1 ton of Indiana block coal. At $4 per ton for coal the fuel cost for 4 acre-inches lifted 26 feet high was 72 cents, which makes six such irrigations cost for fuel alone $4.32, or, upon the basis of a 20-foot lift, $3.03. It should be stated regarding this case that the cost includes the waste of fuel incident to frequent stopping and starting and to firing up in the morning and allowing the engine to cool down at night.

The pump used in the case just cited was a No. 4 centrifugal. For lifts not greater than 25 feet centrifugal pumps are the best for irrigation on account of their simplicity of construction and long life, cheapness, and small liability of getting out of order.

The different types of rotary pumps are very effective when new and in perfect working order, and water can be lifted with them to any desired height, but they are subject to rapid deterioration, especially if there is much silt in the water. Neither of these types of pumps can be advantageously used where they must be placed more than 10 to 20 feet above the water supply.

Some form of plunger pump is necessarily resorted to in wells where the water is more than 20 feet below the surface, and in using such pumps for irrigation purposes, especially where the driving power is limited, it is very important that the suction and discharge pipes shall have diameters nearly or quite equal to the diameter of the plunger itself, otherwise the loss of power through concussion, friction, and unnecessary velocity of discharge will be great.

WATER FOR IRRIGATION FROM WELLS.

The ordinary farm well as it is generally constructed can not be depended upon to supply water for the irrigation even of kitchen gardens of any considerable size. It is possible, however, so to construct farm wells that they will yield much larger supplies of water than they ordinarily do. The most common fault with farm wells is that they do not extend deep enough below the lowest seasonal level of standing water in the ground. When a large supply of water from a well is desired at all seasons of the year, the depth of standing water must be great unless the water is derived from a stratum of gravel or coarse sand, and usually the deeper the water is in the well the more water can be drawn from it, other conditions being similar. Where water is obtained in sandstone in which the wells are drilled, the larger the diameter of the well and the deeper the water in the well the more water it will supply. But where the sandstone is much fissured, so that the water can percolate into fissures and flow along the fissures to the well, the supply of water from it is very much increased.

There is at Babcock, Wis., a 6-inch well 74 feet deep, the last 35 feet of which is in sandstone from which the water is derived, and the natural depth of the water in the well is about 68 feet. This well yields daily 76,800 gallons, which is enough to irrigate, if pumped to full capacity 10 hours per day, 5.89 acres 2 inches deep every 10 days, and 2.95 acres 4 inches deep in the same time. Or, pumped continuously, it might be made to irrigate 14.14 acres 2 inches deep or 7.07 acres 4 inches deep every 10 days.

These figures serve to show the maximum areas which can be irrigated from wells except in those sections which are underlaid by artesian waters under sufficient pressure to cause them to rise to or overflow the surface.

A 10-inch well at Madison, Wis., 750 feet deep has a tested capacity of 599,040 gallons every 24 hours. If this were pumped continuously it would be sufficient to irrigate 110 acres 2 inches deep every 10 days, and 55 acres 4 inches deep. Or, if the well worked 10 hours per day the areas irrigated would be 46 acres 2 inches and 23 acres 4 inches deep.

As an extreme example of the amount of water which may be supplied by a single artesian well that of Chamberlin, S. Dak., may be cited. This well yields 5,000 gallons per minute at a temperature of 71.6° F., or enough to irrigate 657 acres of land to a depth of 4 inches once in 10 days throughout the year.

THE CONSTRUCTION OF RESERVOIRS.

Reservoirs are necessary where pumps are used for purposes of irrigation, particularly if windmills are used. The location of the reservoir should be such that its level is above that of the land to which it is to

supply water. The deeper the reservoir can be made the less will be the loss by evaporation and usually also by leakage, but if the water supplied to it is too cold to use it will warm faster in a shallow reservoir.

Where the soil is of a clayey nature a very good reservoir may be made by first plowing and removing the sod to a distance beyond the border of the proposed walls, because if introduced into the wall it will leak. The earth is then plowed and scraped into a broad ridge having the inside slanting in order that the waves shall not erode the embankment. While the earth is being deposited in the wall it should be trampled firm and close. When the proper height and form has been given to the walls of the reservoir it is necessary to plow and thoroughly pulverize the bottom to a depth of 5 inches preparatory to puddling it. If the reservoir is circular in outline the loosened soil should be first wet at the center and thoroughly puddled there by trampling with a team. Then by widening the wet area the team may be driven round and round until the sides are reached and the whole thoroughly

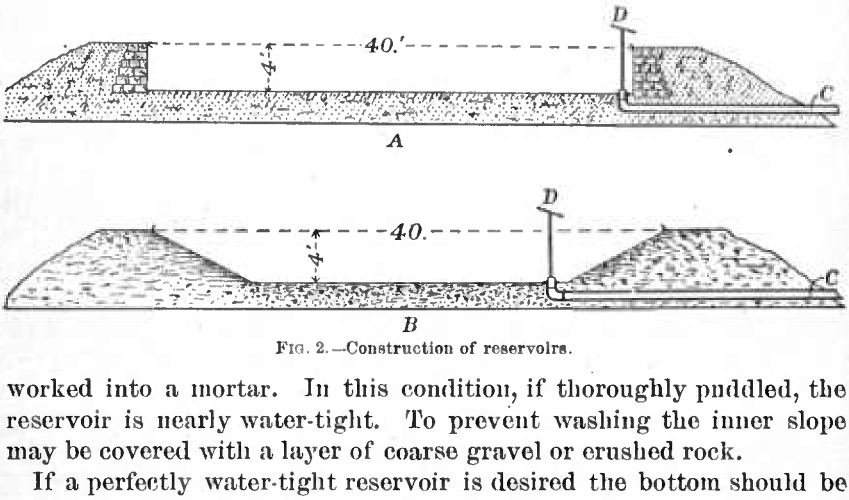

Fig. 2.—Construction of reservoirs.

worked into a mortar. In this condition, if thoroughly puddled, the reservoir is nearly water-tight. To prevent washing the inner slope may be covered with a layer of coarse gravel or crushed rock.

If a perfectly water-tight reservoir is desired the bottom should be cemented, coated with asphalt and sand, or 6 or 8 inches of brick clay used in the puddling.

The reservoir at the Wisconsin Station is cemented on the unpuddled earth bottom and on the sides, which are of stone and vertical. After the cement had become dry the surface was painted with coal tar (boiled until thick) when cold, and applied with a broom from a pail. In this condition it is water-tight.

To remove the water from the reservoir the best plan is to use lap-weld steam pipe provided with an elbow and laid with the mouth of the elbow level with the bottom of the reservoir and facing up; this is closed with a plug to which a long T-handle is attached. Fig. 2 represents a cross-section of reservoir with plug inserted in the discharge pipe. The end of the pipe where the plug is inserted should be thoroughly embedded in a large mass of cement heavy enough to prevent

it from being shaken when the plug is taken out or inserted. A reservoir with sloping sides should have the outlet at the junction of the side and bottom, and it will be necessary to build a pier out to it in order to reach the plug.

A reservoir 4 feet deep and 40 feet in diameter will hold water enough to irrigate 0.35 acre 4 inches deep and 0.69 acre 2 inches deep, and 100 feet in diameter will irrigate 4.32 and 2.16 acres 2 and 4 inches deep, respectively.

METHODS OF APPLYING IRRIGATION WATER.

The methods of applying water are so various that only a lengthened discussion can convey a clear idea of them, but it is believed that the following brief suggestions, condensed from a recent article by Prof. L. R. Taft,[1] will be helpful to those desiring a general knowledge of methods of applying irrigation water to gardens and orchards.—[ED.]

The method by which water will be carried upon the land will depend largely upon the surroundings. If there is a large amount of water and an easy grade can be secured, it may be carried in open ditches, which can be easily excavated with a plow and scraper. Where the distance is not great, or if the pressure is considerable, particularly if the water is pumped, riveted sheet-iron tubing or steel gas pipe can be used. These are readily put together and taken apart as desired, and gates and water plugs may be attached at will. If arrangements are made to drain the pipes, or if they are taken up in winter, they may be placed upon or near the surface.

The size of the pipes needed will depend upon circumstances. For tracts of from 5 to 10 acres a sewer pipe 4 inches in diameter is desirable, although a 3-inch pipe would answer if there is a fair fall. When using iron pipe the size of the distributing pipes upon tracts of a half acre or over should be 2 or, better, 2½ inches. For the main supply pipe from the pump or reservoir a somewhat larger size will lessen the friction and increase the capacity of the system, but if the distance is considerable it will cause a large outlay, and it might be cheaper in the end to use a smaller size and take a little more time. Wooden or sheet-iron flumes may also be used for carrying the water.

The supply pipe or ditch should take the water to the highest point of the tract to be irrigated, and, if the land is uneven, with several knolls, a branch pipe should be carried to each of them. If there is one point from which the water will flow over all others, it can be distributed from that point in flumes or ditches to the furrows and thus spread over the land. While this will lessen the expense if pipes are used, it will be better not to attempt to water more than 1 or 2 acres from a single hydrant. If applied from a hose, it is not desirable to have the hydrants more than 200 feet apart, requiring a hose 100 feet long. For a tract not over 200 feet wide and from 300 to 500 feet long, measuring down the slope, a single hydrant at the middle of the upper side will be sufficient. A regular hydrant can be constructed if desired, but if there is a T with a gate valve at the point where the hose is to be attached it will answer every purpose.

One of the best methods of distributing the water from the hydrants is by the use of wooden troughs. They may be put up permanently along the head of the rows or may be made portable in sections of 16 feet. They should be from 6 to 8 inches square inside or 8 inches deep if triangular. Along one side, at intervals of from 3 to 20 feet, according to the crop for which they are to be used, there should be holes from 1½ to 2 inches in diameter, closed by zinc or galvanized sheet-iron gates. If

[1] U. S. Dept. Agr. Yearbook 1895, p. 233.

the land slopes much, there should be an occasional drop in them. To control the flow of the water, wooden sliding gates are desirable at frequent intervals and at the end of each section of trough. By means of the small gates the water can be distributed to a number of rows at a time and the flow can be regulated at will.

If neither troughs nor pipes are used, an open ditch can be run along the head row, and this will serve the same purpose. If ditches are used, it is desirable that small wooden boxes, closed at one end with a sliding gate, be placed at points where the water is to be drawn out, but the water is often applied by making openings in the bank through which it can be drawn.

Having the water upon the land, it can be applied in various ways. Flooding or allowing the water to spread over the surface to the depth of from 2 to 10 inches was formerly extensively used, but it is now employed only for grain and similar crops. The most common method for vegetables and fruits is to make furrows and run the water along in them, so that it can soak into the soil. If properly arranged, the water can not spread upon the surface, and, by turning back the furrows as soon as the water has soaked in and cultivating the soil, the moisture can be prevented from evaporating (fig. 3).

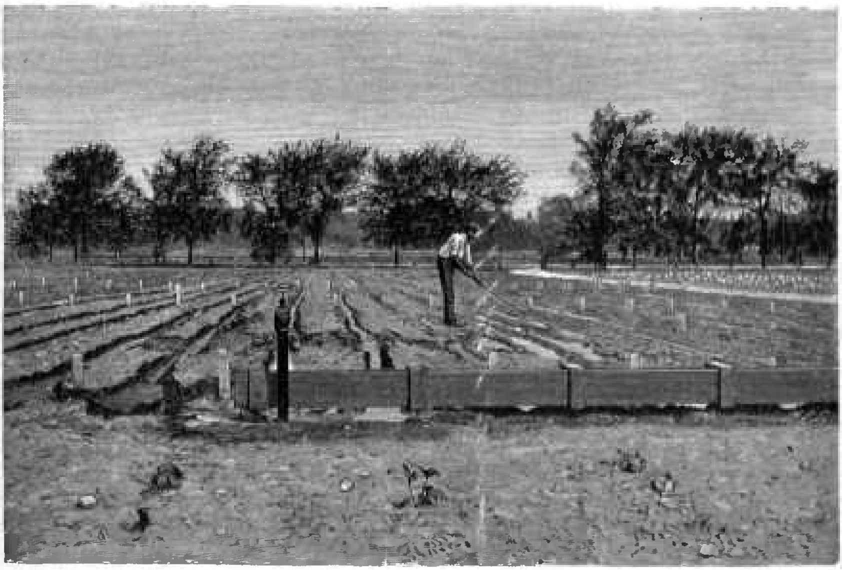

FIG. 3.—Furrow method of irrigation.

Care should be taken to so lay out the rows in the orchard or garden that the furrows for the water can be run at a very slight slope, 2 or 3 inches in 100 feet being all that is desirable, while 1 foot in 100 feet is an extreme slope. With a little care in laying out the furrows water can be used upon land that at first sight it will seem impossible to irrigate.

Subirrigation is the term applied to the running of water through pipes laid below the surface of the ground and allowing it to soak out through cracks or holes made for the purpose. The pipes are generally common drain tiles, from 2½ to 4 inches in diameter, laid at depths of from a few inches to 2 or 3 feet. Particularly upon muck or swampy land, if they are placed at a considerable depth, they will do good service as drains, besides distributing water in dry season. By having the ends of the lines of tile open into a ditch, the water can be carried off when there is a surplus, while, by damming the ditch and filling it with water, the tiles will carry it back for several hundred feet and moisten a space upon either side of from 15 to 40 feet.

They should be placed 12 inches deep in garden loam soil at a distance of 12 or 15 feet apart, but in very light sand or stiff clay shorter intervals will be advisable. The tiles should have a very slight slope, for if there is much head the water will break out unless they are laid at a considerable depth. Several lines may be joined to a larger line laid across their ends, although if each line of tile is supplied independently, a more even distribution will be obtained.

Upon a small garden where the water supply is small, or if it is delivered in small pipes, this method of watering is of value, as the water needs only to be turned on and it will distribute itself without further attention.

While there is a saving of labor in this method, the cost of tiles and the expense of laying them make it much more expensive than furrow irrigation. It has few advantages over furrows for fruits and the ordinary garden crops. As water can be applied in furrows for fruits or large areas of vegetables at from 50 cents to $1.50 per acre, according to the crop and the amount of water available, one can not afford to go to the expense of fitting the land for subirrigation, except where the tiles are needed as drains.

For flower beds and lawns where water can not be applied in furrows tiles can often be used to good advantage. Placed at the depth of 1 foot and as nearly level as possible, they will distribute the water quite evenly over a space from 8 to 16 feet in width. For short lengths the flow of the water should be restricted to the amount that can be given off by the tiles.

For garden crops grown in rows more than 2 feet apart, the water can be run in furrows made a few inches from each row while the plants are small, and halfway between them when they have filled the ground with their roots. For narrower rows, down to 16 inches, it will answer if furrows are made in every second row, while for crops grown in very close drills irrigation may be provided for by leaving a slightly wider space every fourth row in which to run the water. When the crops are sown broadcast, the water may be applied by making furrows from 4 to 10 or even more feet apart, and it will be of far more value than when spread upon the surface.

The condition of the plants is the best indication of the necessity for applying water. If in a time of drought the leaves wilt or curl, or take on an unnatural, dark color, water can generally be used to advantage. Although one or more waterings are occasionally necessary while the plants are small, potatoes, tomatoes, peas, and similar crops are more likely to suffer from lack of water after the fruits and tubers form, and it should then be used in liberal quantities. For all such crops it is seldom desirable to irrigate while the plants are in blossom, as it tends to start a new growth and prevent setting. After the crop has set, particularly in case of the potato, no check to the growth should be allowed from lack of water, as when it is applied a new growth will start, a second crop will set, and the result will be a large number of small potatoes.

More than 800 to 1,500 barrels per acre should not be applied at one time, as, if heavy rains follow, the ground may be saturated. Even with the most thorough cultivation, anywhere from a half inch to 2 inches of water per week can be used to advantage by vegetables during May, June, July, and August, and unless the natural supply available approximates that amount it should be supplied artificially in proportion to the character of the soil and season and the needs of the crop, 1 inch being taken as an average for each application for good garden soils. Care should be taken to prevent the flowing of the water over the surface, and particularly from coming in contact with the stems and leaves of the plants. After each watering and after every rain the ground should have a shallow cultivation, and this should be repeated at least once a week.

For orchards as well as for other crops it is better to use a number of small streams rather than one or two strong ones, as there will be less washing of the soil, and a more even distribution of the water can be secured. A flume or head ditch will aid very much in securing this.

In locating the rows such an arrangement should be made as will secure a proper slope for the furrows, which should be from 1 to 6 inches in 100 feet. While the trees are small a furrow upon either side of each row will answer, but as the roots spread additional furrows 3 or 4 feet apart should be made, until finally the entire space is irrigated (fig. 4). Too much water and too frequent applications are more likely to be harmful than too little water, and ordinarily there will be no necessity for watering until the fruit is half grown, and from one to three applications, the last one not later than the middle of August, in order to allow the growth to ripen, will usually suffice. The use of water during a week or two before and continuing until two weeks after blossoming is not desirable.

Great injury is often done by the drying out of the trees in winter, and if the autumn is very dry it will be well to irrigate the trees just before the ground freezes. The amount of water required by orchards is from 1 to 2 inches at each application, while the frequency of watering must depend upon conditions. When a loam soil

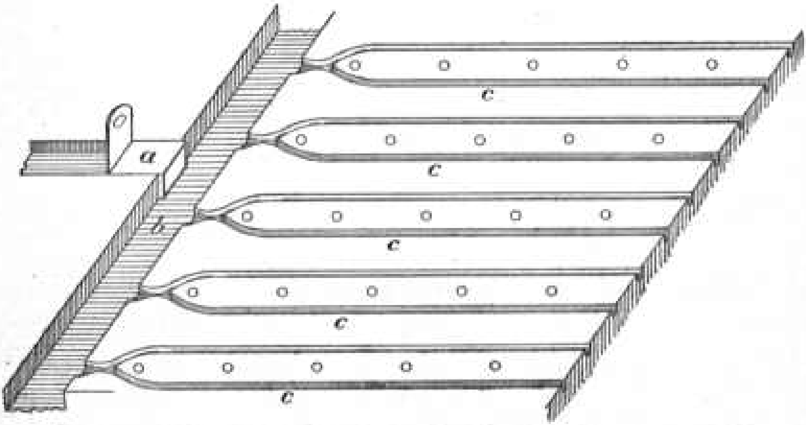

FIG. 4.—Irrigating young orchard with furrows: *a*, sluice; *b*, head ditch; *c*, furrows.

taken from a depth of 5 or 6 inches will not pack in the hand it is an indication that water is needed. Ordinarily once in from two to three weeks is as often as water need be applied.

Basins or checks can often be used to advantage when the ground is uneven or sloping. They are formed by scraping the soil away so as to form ring-like depressions about the trees, into which the water is turned. They should have a diameter equal to that of the branches, and the amount of water used should be sufficient to cover the area occupied by the roots to the depth of at least an inch.

The method of watering strawberries and other small fruits is not unlike that used for vegetables. The water is run down the center of the rows in furrows, or, better yet, close alongside the rows. If the ground is very dry in the spring, a good watering may then be given, but after growth has started no water should be given until the fruit has set, after which the irrigation may be kept up as needed at intervals of two or three weeks until the fruit is gathered. All except the grape may need an occasional application after that time, and if the ground is dry as winter comes on an application at that time is desirable.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

No. 15. Some Destructive Potato Diseases: What They Are and How to Prevent Them. Pp. 8.
No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24.
No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
No. 21. Barnyard Manure. Pp. 32.
No. 22. Feeding Farm Animals. Pp. 32.
No. 23. Foods: Nutritive Value and Cost. Pp. 32.
No. 24. Hog Cholera and Swine Plague. Pp. 16.
No. 25. Peanuts: Culture and Uses. Pp. 24.
No. 26. Sweet Potatoes: Culture and Uses. Pp. 30.
No. 27. Flax for Seed and Fiber. Pp. 16.
No. 28. Weeds; and How to Kill Them. Pp. 30.
No. 29. Souring of Milk, and Other Changes in Milk Products. Pp. 23.
No. 30. Grape Diseases on the Pacific Coast. Pp. 16.
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No. 37. Kafir Corn: Characteristics, Culture, and Uses. Pp. 12.
No. 38. Spraying for Fruit Diseases. Pp. 12.
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